SCH4U Assignment: Equilibrium Calculations Name: ____________________

1. At a certain temperature, *Keq* for the following reaction between sulfur dioxide and nitrogen dioxide is 4.8.

$SO2(g) + NO2(g) \leftrightarrow NO(g) + SO3(g)$

SO2(g) and NO2(g) have the same initial concentration: 0.36 mol/L. What amount of SO3(g) is present in a 5.0 L container at equilibrium?

mol/L	SO_2 +	NO_2	⇌ NO +	SO_3
I	0.36	0.36	0	0
C	$-x$	$-x$	$+x$	$+x$
E	$0.36-x$	$0.36-x$	x	x

$x = 0.25$ M

$$K_{eq} = \frac{[NO][SO_3]}{[SO_2][NO_2]}$$

$$4.8 = \frac{(x)(x)}{(0.36-x)^2}$$

$$\sqrt{4.8} = \sqrt{\frac{x^2}{(0.36-x)^2}}$$

$$2.19 = \frac{x}{0.36-x}$$

$$2.19(0.36-x) = x$$

$$0.788 - 2.19x = x$$

$$0.788 = x + 2.19x$$

$$\frac{0.788}{3.19} = \frac{3.19x}{3.19}$$

$$x \approx 0.25 \text{ M}$$

Asking:

n_{SO_3} in 5.0 L

$n = C \times V$

$= 0.25 \times 5.0$

$= 1.3$ mol

2. When 1.0 mol of ammonia gas is injected into a 0.50 L flask, the following reaction proceeds to equilibrium.

$2NH_3(g) \leftrightarrow N_2(g) + 3H_2(g)$

At equilibrium 0.30 mol of hydrogen gas is present.

(a) Calculate the equilibrium concentrations of $N_2(g)$ and $NH_3(g)$.

(b) What is the value of *Keq*?

$1.0/0.5 = 2.0$ M

$\frac{0.30}{0.50} = 0.60$ M

M	$2NH_3$	$\leftrightarrow$ N_2	+ $3H_2$
I	2.0	0	0
C	$-2x$	$+x$	$+3x$
E	$2-2x$	x	$3x$

$$K_{eq} = \frac{[N_2][H_2]^3}{[NH_3]^2}$$

$[H_2]_{eq} = 0.60$ M

$3x = 0.60$

$x = 0.20$

$[NH_3]_{eq} = 2 - 2(0.20) = 1.60$

$[N_2]_{eq} = 0.20$

$$K_{eq} = \frac{(0.20)(0.60)^3}{(1.60)^2} = 1.7 \times 10^{-2}$$

3. Phosphorus trichloride reacts with chlorine to form phosphorus pentachloride. $PCl_3(g) + Cl_2(g) \leftrightarrow PCl_5(g)$
0.75 mol of PCl_3 and 0.75 mol of Cl_2 are placed in a 5.0 L reaction vessel at 500 K. What is the equilibrium concentration of the mixture? The value of *Keq* at 500 K is 49.

$$\frac{0.75}{5.0} = 0.15$$

mol/L	PCl_3 +	Cl_2 $\leftrightarrow$	PCl_5
I	0.15	0.15	0
C	$-x$	$-x$	$+x$
E	$0.15-x$	$0.15-x$	x

$$K_{eq} = \frac{[PCl_5]}{[PCl_3][Cl_2]}$$

$$49 = \frac{x}{(0.15-x)^2}$$

$$49(0.0225 - 0.3x + x^2) = x$$

$$1.1025 - 14.7x + 49x^2 - x = 0$$

$$49x^2 - 15.7x + 1.1025 = 0$$

$$x^2 - 0.320x + 0.0225 = 0$$

$a = 1 \quad b = -0.320 \quad c = 0.0225$

$$x = \frac{+0.320 \pm \sqrt{(0.32)^2 - 4(0.0225)}}{2}$$

$$x = (0.320 \pm 0.111)/2$$

$$z_1 = \frac{0.320 + 0.111}{2} \quad \text{or} \quad \frac{0.320 - 0.111}{2}$$

$= 0.22$ Rejected.

0.11 ✓

$$[PCl_3]_{eq} = 0.15 - 0.11 = 0.04\ M \qquad [Cl_2]_{eq} = 0.04\ M$$

$$[PCl_5]_{eq} = 0.11\ M$$

4. Hydrogen gas has several advantages and disadvantages as a potential fuel. Hydrogen can be obtained by the thermal decomposition of water at high temperatures.

$2H_2O(g) \leftrightarrow 2H_2(g) + O_2(g)$ $K_{eq} = 7.3 \times 10^{-18}$ at 1000°C

(a) The initial concentration of water in a reaction vessel is 0.055 mol/L. What is the equilibrium concentration of $H_2(g)$ at 1000°C?

(b) Comment on the practicality of the thermal decomposition of water to obtain $H_2(g)$.

M	$2H_2O$ ↔	$2H_2$ +	O_2
I	0.055	0	0
C	$-2x$	$+2x$	$+x$
E	$0.055 - 2x$	$2x$	x

$\frac{0.055}{7.3 \times 10^{-18}}$ >>> 1000 simple math!

{ [Reverse Rxn is the only reaction happening]

$\therefore [H_2O]_i \doteq [H_2O]_{eq}$

$K_{eq} = \frac{(x)(2x)^2}{(0.055)^2}$ $(x)(4x^2)$

$7.3 \times 10^{-18} = 4x^3 / 0.00303$

$$\frac{(7.3 \times 10^{-18})(0.00303)}{4} = x^3$$

$$\sqrt[3]{5.53 \times 10^{-21}} = x$$

$$1.8 \times 10^{-7}\ M = x$$

$$[H_2]_{eq} = 2(1.8 \times 10^{-7})$$
$$= 3.6 \times 10^{-7}\ mol/L$$

b) Not Practical.

5. The following reaction takes place inside a cylinder with a movable piston. $2NO_2(g) \leftrightarrow N_2O_4(g)$

At room temperature, the equilibrium concentrations inside the cylinder are $[NO_2] = 0.0206$ mol/L and $[N_2O_4] = 0.0724$ mol/L.

(a) Calculate the value of *Keq*.

(b) What will happen if a piston is used to halve the volume of the reaction mixture? Explain why.

(c) Determine the value of *Quotient, Q,* when the volume is halved.

(d) What does the value of Q suggests about the rate of forward and reverse reactions?

5a) $K_{eq} = \frac{[N_2O_4]}{[NO_2]^2}$ $\qquad C = \frac{n}{V}$

$= \frac{0.0724}{(0.0206)^2}$ $\qquad C = \frac{n}{\frac{1}{2}V}$

$= 171$ $\qquad C = 2\frac{n}{V}$

b) stress is: P ↑ the system will oppose by lowering pressure by moving forward to make less gas particles.

Le Châtelier

c) $Q = \frac{2(0.0724)}{(2 \times 0.0206)^2}$

$= 85.3$

d) $Q < K_{eq}$ ∴ the forward reaction is favoured to make more product

#6) At a certain temperature, $K_{eq} = 4.0$ for the following reaction.

$2HF(g) \leftrightarrow H_2(g) + F_2(g)$

A 1.0 L reaction vessel contained 0.045 mol of $F_2(g)$ at equilibrium.

What was the initial amount of HF in the reaction vessel?

M	2Hf	H_2	f_2
I	y	0	0
C	$-2x$	$+x$	$+x$
E	$y-2x$ 0.023 M	x	x

Given

$$[F_2]_{eq} = \frac{0.045\ m}{1.0\ L} = 0.045\ M$$

$$[H_2] = 0.045\ M$$

$$[HF] = y - 2(0.045) = y - 0.090$$

$$K_{eq} = \frac{[f_2][H_2]}{[HF]^2}$$

$K_{eq} \leftarrow 4.0$

$$4.0 = \frac{(0.045)(0.045)}{(y-0.090)^2}$$

[illegible]

$$4.0 = \frac{(0.045)^2}{z^2}$$

$$z^2 = \frac{(0.045)^2}{4.0}$$

$$z = \pm\sqrt{5.06 \times 10^{-4}}$$

$$z = + 2.3 \times 10^{-2}\ M$$

$$y = z + 0.090$$

$$y = 2.3 \times 10^{-2} + 0.09$$

$$= 1.1 \times 10^{-1}\ M$$